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THE COMMERCIAL STORAGE OF FRUITS  
VEGETABLES, AND FLORISTS' STOCKS

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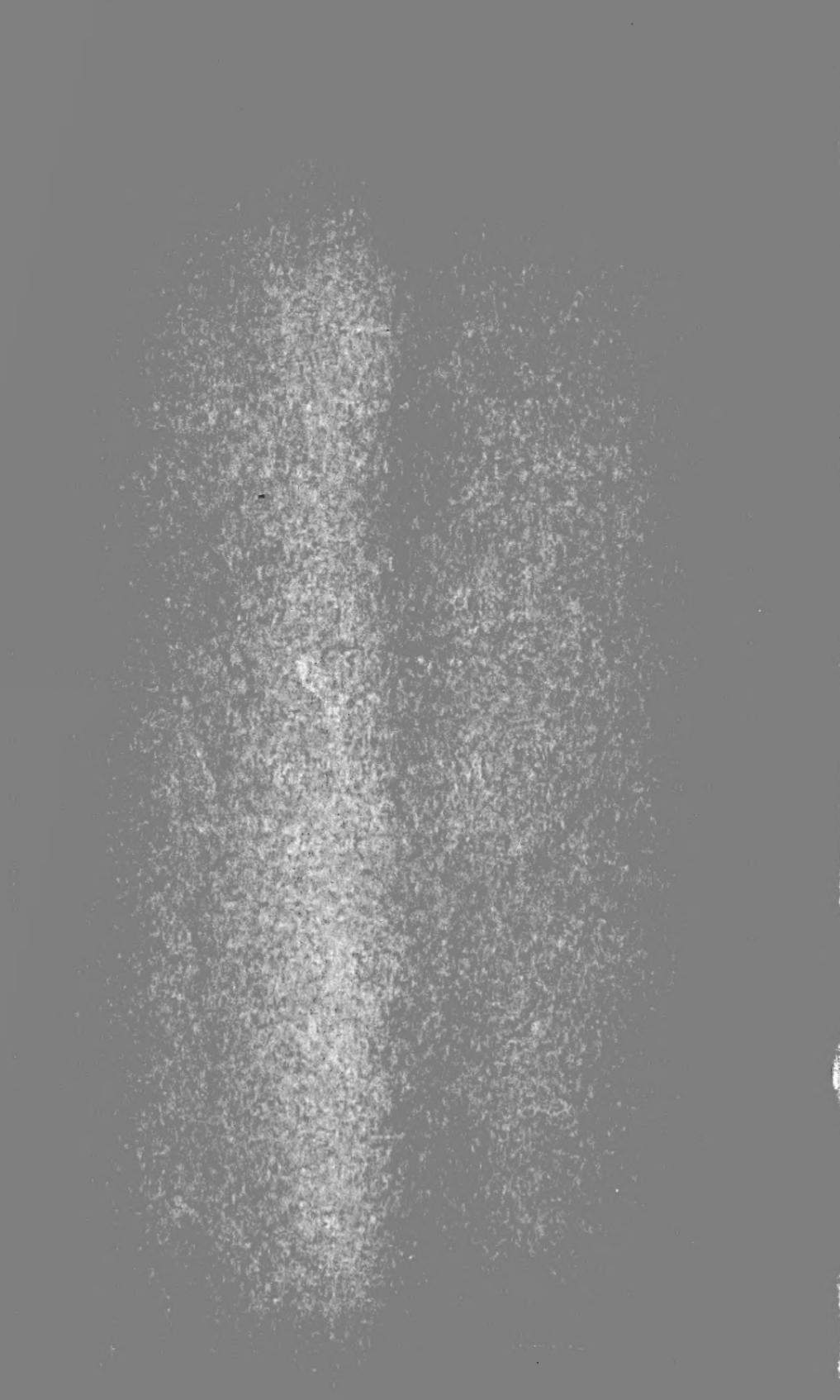
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# THE COMMERCIAL STORAGE OF FRUITS, VEGETABLES, AND FLORISTS' STOCKS

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## INTRODUCTION

The purpose of this circular is to present a series of brief summaries of the essential average storage requirements of most of the more important varieties of fresh fruits, vegetables, cut flowers, and certain other perishable commodities which enter the market on a commercial scale. Many details are of necessity omitted, as the work is intended primarily for general practical reference. The conditions given should not be considered as absolute or final, but rather as the safe limitations under which the various products can ordinarily be stored. Detailed information on the handling and storage of some of the commodities discussed is available elsewhere.

in the form of bulletins or textbooks; for many of them only general information exists.

Fresh fruits, vegetables, cut flowers, etc., intended for storage should be as free as possible from skin breaks, bruises, and decay. They should be neither immature nor overmature, because in either case it may be difficult to keep them from too rapid deterioration, and even if they do not change appreciably in storage, they will not be commercially desirable when removed. The proper degree of maturity in each case can usually be determined by consulting the various sections of this circular or the other publications listed in Literature Cited (p. 37), or on the basis of previous experience. There is a seasonal variation, however, in the storage quality of certain products, particularly fruits; hence care must be taken not to assume too much from 1 year's experience concerning the probable behavior of a given commodity grown the next year.

Decay and other deterioration in storage is too broad a subject to be discussed in detail in this publication. It is discussed very generally in connection with various fruits and vegetables covered by this circular and in greater detail in other publications (1, 2, 4, 10, 11, 12, 13, 20, 21, 22, 23, 24, 26, 29, 31).<sup>1</sup>

#### FACTORS INVOLVED IN COLD STORAGE

Details of the best conditions for the storage of fresh fruits, vegetables, and cut flowers are subject to change from time to time as more definite information is gained in the handling of these commodities. The conditions and requirements given in this circular are derived from the best commercial practice at the present time and from scientific experimentation. All of the temperature requirements are given in degrees Fahrenheit and represent the average air temperatures that should be maintained. The humidities are relative and are expressed in percentage of saturation; for example, when it is stated that a certain humidity should be 85 percent, this means that the air should be at approximately 85 percent of complete saturation with water vapor at the recommended temperature.

The term "cold storage" refers to storage where the desired temperature is maintained by mechanical means; the term "common storage" is used where the natural outdoor temperature, modified or controlled as far as possible by means of insulated walls and ventilators, is depended upon to maintain the desired storage temperature. The storage period given in each case includes the transit period if there is one. Allowance has been made for the facts that the temperature of fruits and vegetables in transit is usually higher than the recommended storage temperature and that ripening or other changes are likely to go on more rapidly during a given transit period than during the same length of time in cold storage.

#### TEMPERATURES OF STORAGE ROOMS

If the best results are to be obtained in the cold storage of the products discussed herein it is highly important that the tempera-

<sup>1</sup> Italic numbers in parentheses refer to Literature Cited, p. 37.

ture in storage rooms be held fairly constant. Variations of 2 or 3 degrees above or below the desired temperature are in most cases too large. They can usually be avoided if the storage rooms are well insulated throughout and are furnished with adequate refrigeration and equipped either with reliable, accurate thermostats or with means for manual control which are given frequent personal attention by some one charged with that duty. Even when reliable automatic controls are used, frequent personal visits to storage rooms should be made.

In commercial cold-storage rooms thermometers are usually placed at about the level of the eyes of a man of ordinary height, sometimes slightly lower. It is important however to take temperatures frequently at the floor and the ceiling also, or at any other places where they might be expected to be undesirably high or low. If the air in certain locations seems always to be too warm or too cold it may be necessary to install fans to increase the rate of air movement and so bring about a better equalization of the temperature in various parts of the room.

Most varieties of apples keep best and longest if held constantly at  $31.5^{\circ}$  to  $32^{\circ}$  F.; the best temperature for Bartlett pears is between  $30^{\circ}$  and  $31^{\circ}$ . If the air temperature where either of these fruits is stored rises 2 or 3 degrees above the upper limit mentioned, there is danger of increased decay and undue ripening, the danger being greater the longer the period during which the temperature is above  $32^{\circ}$ . For example, 3 or 4 days at  $35^{\circ}$  usually would have little or no effect, partly because of a slower rise in the temperature of the fruit than in that of the air; but 10 days at this temperature would probably shorten the life of the fruit by about a week and possibly result in more decay. On the other hand, if the temperature goes a degree or two below  $30^{\circ}$ , there is a chance that freezing will occur. Celery and cabbage allowed to remain too warm in storage may show yellowing and decay; potatoes are likely to begin to sprout if the temperature is too high and usually become undesirably sweet if it is too low. Other commodities undergo these or other kinds of deterioration if the temperature variations throughout long storage periods exceed the limits given for them in this publication. In addition, there is always the possibility that fluctuations in temperature will cause condensation of moisture on stored products, which in itself is undesirable because it favors the growth of mold and the development of decay.

Control of temperature is usually easier in large rooms than in small ones if both are filled to capacity. This is because of the "flywheel" effect produced by the larger mass of material including both the commodity and the building material. Refrigeration is thus stored up, so to speak, and temperature changes occur more slowly. For this reason small storage rooms generally will require closer attention than large ones.

#### HUMIDITY OF STORAGE ROOMS

The relative humidity of the air in storage rooms has a direct relation to the keeping quality of the products held in them. If it is too low, wilting is likely to occur in most fruits, vegetables, cut flowers,

etc.; if it is too high, it favors the development of decay especially in rooms where there is considerable variation in temperature. The control of humidity is rather difficult, however, and is not often attempted in commercial storage warehouses. Operators of certain large cold-storage houses have found that when a room is filled with apples or celery, for example, the relative humidity soon becomes constant at a fairly definite level which fortunately is about the optimum for the particular commodity concerned. The same result has been observed with other commercially important fruits and vegetables and probably is obtained in many of the larger, well-constructed cold-storage warehouses of the country.

For most fruits that are stored commercially the general statement can be made that a relative humidity of 80 to 85 percent gives the best results. Exceptions are discussed in the text. For leafy vegetables and root crops the relative humidity should be about 90 to 95 percent; for other vegetables, except as noted in the text, 85 to 90 percent. If it seems necessary to increase the relative humidity in rooms used for common or air-cooled storage, this can best be done by sprinkling the floor occasionally. Earth floors are more desirable in air-cooled storages than floors of concrete because they are more easily kept damp.

Various methods have been proposed or tested for the control of humidity in cold-storage rooms, but at present there seems to be no general agreement among operators of cold-storage plants as to which is the best of these methods nor has there been widespread use of any of them.

#### EVOLUTION OF HEAT BY COMMODITY

In any consideration of the storage of fresh fruits and vegetables, cut flowers, etc., it should be remembered that these commodities are alive and by virtue of that fact they carry on within themselves many of the processes characteristic of all living things. Unless the relative humidity is high, they give off moisture to the surrounding air and most of them, in time, become shriveled or wilted, even at 32° F. The enzymes or ferments they contain act on various substances in their tissues and gradually bring about changes in color, texture, and chemical composition which mature the commodity and may result in serious deterioration or even complete breakdown. The most important of these changes are produced by respiration, the process in which the oxygen of the air is combined with the carbon of the plant tissues, occurring chiefly in sugars, to form various decomposition products and eventually carbon dioxide and water. During this process energy is released in the form of heat, the amount of which varies with the commodity and increases as the temperature increases, up to about 100°. This heat is always a part of the refrigeration load which must be considered in handling fruits, vegetables, and cut flowers in cold-storage rooms or refrigerator cars. The approximate rate of evolution of heat by various commodities is given in table 1.

TABLE 1.—*Approximate rate of evolution of heat by certain fresh fruits and vegetables when stored at temperatures indicated*

Commodity	Tem- pera- ture (° F.)	British ther- mal units of heat per ton of fruits or vege- tables per 24 hours <sup>1</sup>	Litera- ture refer- ences
Apples	32	660- 880	(15)
	40	1,110- 1,760	
	60	4,400- 6,600	
Bananas:	85	6,600-15,400	(17)
	54	3,300	
	68	8,360	
	68	9,240	
Beets	68	8,360	(1)
	32	1,166	
	40	1,870	
Beets	60	3,476	(1)
	32	213	
	40	506	
Cantaloupe	60	3,938	(1)
	32	814	
	40	1,408	
Carrots	60	3,806	(1)
	32	704	
	40	2,606	
Celery	60	5,862	(1)
	32	1,320- 1,760	
	60	11,000-13,200	
Cherries (sour)	32	460	(7)
	40	1,070	
	60	2,770	
Grapefruit	80	4,180	(8)
	35	660- 1,100	
	60	2,200- 2,640	
Grapes (Cornichon and Flame Tokay)	80	5,500- 6,600	(7)
	32	580	
	40	810	
Lemons	60	2,970	(8)
	80	6,200	
	77	2,200- 3,300	
Lettuce	32	638	(5)
	40	7,392	
	60	22,660	
Onions (Yellow Globe)	32	660- 1,100	(1)
	50	1,760- 1,980	
	70	3,080- 4,180	
Oranges	32	690- 900	(8)
	40	1,400	
	60	2,710- 2,970	
Peaches	80	8,000	(7)
	35	1,540- 1,980	
	60	6,600-13,200	
Pears (Bartlett)	80	15,400-22,000	(14)
	32	850- 1,370	
	40	1,440- 2,030	
Peppers	60	7,260- 9,310	(8)
	80	17,930-22,460	
	32	660- 880	
Potatoes (Irish Cobbler)	60	8,800-13,200	(1)
	32	550	
	40	1,518	
Raspberries	60	3,322	(2)
	32	440- 880	
	40	1,100- 1,760	
Strawberries	50	1,100- 1,540	(8)
	70	2,200- 3,520	
	35	4,400- 6,600	
Strawberries	60	15,400-17,600	(7)
	35	3,300	
	60	13,200-15,400	
Strawberries	32	2,730- 3,800	
	40	5,130- 6,600	
	60	15,640-19,140	
Strawberries	80	37,220-46,440	

<sup>1</sup> British thermal units. The figures in this column were obtained (1) by assuming that the heat liberated by respiration is produced by the respiration of a hexose sugar, and (2) by multiplying the milligrams of carbon dioxide produced per hour by each kilogram of respiring material by the factor 220.

<sup>2</sup> Unpublished work on the respiration of vegetables by R. C. Wright and T. M. Whiteman.

TABLE 1.—*Approximate rate of evolution of heat by certain fresh fruits and vegetables when stored at temperatures indicated*—Continued

Commodity	Tem- pera- ture (° F.)	British ther- mal units of heat per ton of fruit per 24 hours	Litera- ture refer- ences
String beans.....	32	1,694	(2)
	40	2,706	
	60	10,802	
	32	2,640	
Sweet corn.....	40	3,806	(2)
	60	8,118	
	40	880- 1,320	
	85	6,600- 8,800	
Sweetpotatoes.....	32	0	(9)
	40	132	
	60	2,574	
	32	66	
Tomatoes (mature green).....	40	572	(2)
	60	682	
Turnips.....			

<sup>2</sup> Unpublished work on the respiration of vegetables by R. C. Wright and T. M. Whiteman.

It will be noted that lettuce, Bartlett pears, peaches, and cherries have a much higher respiration rate than potatoes, apples, and onions. This means that the first group requires considerably more refrigeration than the second to keep them at a specified temperature. Less pronounced differences occur between other commodities in the list and are important to a lesser degree in determining the amount of refrigeration necessary to cool them and keep them in sound, usable condition.

It is difficult to determine the heat to be removed in cooling fruits and vegetables to cold-storage temperatures. This depends mainly on the following factors: The specific heat of the product, the rate at which it produces heat (by respiration), and its initial and final temperature. If the product could be cooled to the storage temperature instantaneously, the heat to be removed would be only the number of British thermal units (B.t.u.) or calories obtained by multiplying the specific heat of the product by the difference between the initial and the final temperature, and this result by the weight of the product in pounds or kilograms. This is usually called the sensible heat. The cooling process, however, requires time, and during this interval additional heat is produced by the respiration of the stored fruit or vegetable.

In order to determine the amount of this additional heat it is necessary to know the rate of heat production at any temperature and the length of time the product is in each temperature range. For example, if the respiration rate (or rate of heat production) for a given commodity is twice as great at 70° F. as at 50°, the number of hours this commodity is at each of these temperatures must be known before the total heat produced can be calculated. When fruits and vegetables cool, the rate at which they produce heat decreases, and the total heat produced depends not only upon the time required for cooling but also upon how long the commodity stays in each temperature range.

Table 2 shows the approximate amounts of sensible heat and of heat produced by respiration which must be removed from 7 varieties of 4 kinds of fruit in cooling them from various temperatures to

a temperature of 35° F. These figures are based on experimental determinations of the rate of respiration at various temperatures; some of the data are from the tables given by Magness et al. (13, 15), and the remainder from data reported by Haller et al. (8). The figures for Bartlett pears are based on the maximum values given by Magness (15). The figures given in this table have been obtained by assuming that the heat of respiration is produced by oxidation of a hexose sugar, and can be calculated from the rate of production of carbon dioxide which has been determined experimentally; very few calorimetric measurements of heat production by fruits and vegetables have been made, and this assumption seems to be the best available basis for calculating heat production at any given temperature.

TABLE 2.—*Approximate amounts of heat of respiration and sensible heat to be removed from certain fruits in cooling them from 60°, 70°, or 80° to 35° F. in a room at 32° F., when cooling takes place in 3, 4, 5, 6, 8, or 10 days*

[Heat expressed in B.t.u. per ton of fruit]

Kind of fruit	Initial temperature (°F.)	Heat of respiration during—						Sensible heat <sup>1</sup>
		3 days	4 days	5 days	6 days	8 days	10 days	
Apples:	80	8,000	11,000	14,000	16,000	22,000	27,000	80,000
	70	7,000	9,000	12,000	14,000	19,000	23,000	62,000
	60	6,000	8,000	10,000	12,000	16,000	20,000	44,000
	80	12,000	16,000	20,000	24,000	32,000	40,000	80,000
Grimes Golden	70	10,000	13,000	17,000	20,000	26,000	33,000	62,000
	60	8,000	11,000	13,000	16,000	21,000	27,000	44,000
	80	13,000	18,000	22,000	26,000	35,000	44,000	80,000
Peaches:	80	10,000	13,000	17,000	20,000	26,000	33,000	62,000
	70	7,000	10,000	12,000	14,000	19,000	24,000	44,000
	60	16,000	22,000	27,000	32,000	43,000	54,000	80,000
Carman	70	13,000	17,000	21,000	25,000	34,000	42,000	62,000
	60	10,000	13,000	16,000	19,000	25,000	32,000	44,000
Pears:	70	16,000	22,000	27,000	33,000	44,000	54,000	61,000
	60	13,000	17,000	22,000	26,000	35,000	43,000	43,000
Strawberries:	80	36,000	39,000	49,000	59,000	79,000	99,000	83,000
	70	24,000	32,000	40,000	49,000	65,000	81,000	64,000
	60	19,000	26,000	32,000	39,000	51,000	64,000	46,000
Howard 17	80	38,000	51,000	64,000	77,000	102,000	128,000	83,000
	70	31,000	42,000	52,000	63,000	84,000	104,000	64,000
	60	25,000	34,000	42,000	51,000	68,000	84,000	46,000

<sup>1</sup> For any one kind of fruit at a given temperature these figures are assumed to be the same for all cooling periods included in the table.

The assumption has also been made, although it is known to be only approximately correct, that the rate of temperature drop at any given time during cooling is proportional to the difference between room temperature and fruit temperature at that time. With this assumption as a basis, the temperature and thus the rate of respiration at any time during the cooling period, as well as the total heat produced during the whole cooling period, have been calculated.<sup>2</sup>

As a result of these calculations it has been found that the heat produced by the respiration of fruit while it cools is directly proportional to the length of the cooling period. The figures for cooling periods of 3, 4, 5, 6, and 8 days are therefore set at 3, 4, 5, 6,

<sup>2</sup> The authors wish to acknowledge the valuable assistance given by W. V. Hukill, of the Bureau of Agricultural Engineering, in the making of the calculations and in the preparation of this statement on the production of heat by fruits and vegetables.

and 8 tenths (to the nearest thousand) of the figure for 10 days. The specific heat has been calculated by the formula  $S=0.008a+0.20$  in which  $S$  signifies the specific heat of a substance containing  $a$  percent of water; 0.2 is the value which has been assumed to represent the specific heat of the solid constituents of the substance in question (25).

Column 1 of table 2 shows the kind and variety of fruit and column 2 the temperature of the fruit at the time cooling starts, in a room held at 32° F. The next column shows the amount of heat evolved by respiration if the fruit reaches 35° at the end of 3 days. The next 5 columns show the amount of heat if cooling to 35° requires 4, 5, 6, 8, or 10 days, respectively. The last column is the sensible heat (obtained by multiplying the specific heat of the fruit by the difference between initial and final temperatures and this result by the number of pounds in a ton). For any one kind of fruit at a given initial temperature, this figure is assumed to be the same for all the cooling periods included in the table.

The values given in table 2 are only approximate. The two assumptions that have been made, namely, (1) that the heat of respiration is produced only by the oxidation of a hexose sugar and can be computed from observed amounts of carbon dioxide produced, and (2) that the rate of temperature drop is always proportional to the difference between fruit temperature and room temperature, probably lead to fairly accurate results; but since only a few direct measurements of the heat produced by fruits and vegetables have been made, it is not known just how close the approximation is. The figures are presented to help cold-storage-plant operators estimate the quantity of refrigeration required for cooling the fruits named, and under the various conditions given. As an example of how they can be used, the following calculation may be of interest: A ton of Bartlett pears cooling from 70° to 35° F. in 10 days in a 32° room is shown to be capable of producing about 54,000 B.t.u. Its sensible heat at 70° (35 degrees above its final temperature) is 61,000 B.t.u. The sum of the two is 115,000 B.t.u. If this be multiplied by the capacity of the room in tons of fruit, say 600 (the capacity of some of the commercial cold-storage rooms in the United States), and divided by 288,000 (the number of B.t.u. in a ton of refrigeration), the quotient 239 is obtained; this is approximately the number of tons of refrigeration required to cool 600 tons of Bartlett pears to 35° in 10 days, under the conditions specified. The corresponding figure for Winesap apples is 177 and for Grimes Golden apples, 200.

#### EFFECT OF COLD STORAGE ON SUBSEQUENT BEHAVIOR OF FRUITS AND VEGETABLES

The belief is rather common among those concerned with the marketing of fresh fruits and vegetables that commodities of this kind that have been in cold storage deteriorate more rapidly after removal from the low temperature than if they had been held at ordinary temperatures. It is difficult, however, to find a basis for judging whether or not they actually do so because there is no means known

other than the use of low temperature for checking the ripening and decay so largely responsible for their deterioration. That is, it is impossible in the present state of knowledge to obtain fruits and vegetables that have not been refrigerated but still have not changed in any way since harvest, for comparison with similar lots that have been in cold storage and are eventually removed.

It might be thought that respiration could be used as a basis for judging the effects of cold storage on fruits and vegetables, since this process is one of the important factors in bringing about deterioration. Certain starchy products such as potatoes and bananas that have been held in cold storage respire more rapidly after removal; they produce more carbon dioxide and give off more heat than those which have been held at ordinary temperatures. However, so far as can be discovered, fruits such as peaches, strawberries, oranges, grapefruit, and apples do not. In the case of potatoes and bananas, the reason is thought to be that when these commodities are held at low temperatures, sugar accumulates in their tissues; then when they are removed to higher temperatures, this sugar is readily respired, so that they produce more carbon dioxide and give off more heat than similar lots that have been held continuously at 50° to 60° F. With potatoes, however, the criterion used does not necessarily mean more rapid deterioration. That is, the increase in respiration is not necessarily accompanied by wilting, decay, or discoloration of the flesh.

It can be stated that for most fruits and vegetables, so far as is now known, cold storage is beneficial and not otherwise. Bananas are an exception because if held at temperatures below about 56° F., they become "chilled" and will not ripen properly when removed to a ripening temperature. There is no evidence that the increased respiration of bananas after they are moved to warmer temperatures is accompanied by unusual deterioration.

When fruits or vegetables are removed from a low temperature to a higher one there is frequently a condensation of moisture from the air on the cool surface of the commodity. This is known as sweating and is more marked, the higher the relative humidity of the outside air. It should be prevented whenever possible in the case of onions and the more tender fruits, because it favors the development of decay. This does not mean that when any of these products sweat after removal from an iced refrigerator car or a refrigerated room they are sure to decay; it does mean that they are more likely to decay than if they were dry after being unloaded and remained dry until consumed. In this connection dryness means merely the absence of liquid water on the surface.

Sweating can be prevented to some extent, as in the British practice with eggs and certain other commodities, by allowing the fruits or vegetables to warm up gradually. Under commercial conditions in the United States this is rarely practicable, however, and the best thing to do in very damp weather is to realize the risk, handle the product carefully, and get it into consumption without undue delay.

The storage conditions recommended herein for certain commodities represent either a compromise between two undesirable extremes

of temperature or humidity, or a choice of the least harmful of two such extremes. Grapefruit, for example, suffer less from decay at low humidities than at high; on the other hand, at low humidities they are subject to a pitting which is usually more damaging to the market value of the fruit, because it is more common under commercial conditions than is decay. Therefore, it is recommended that grapefruit in storage be held at about 85 percent relative humidity.

On account of the danger of soggy breakdown (20) in Grimes Golden apples grown under certain conditions, it is sometimes advisable to store this variety at 34° or 36° F. rather than at 32°. The Jonathan variety suffers less from soft scald if stored at 34° to 36° instead of at 32°. It is susceptible, however, to the more common and more serious condition known as "internal breakdown" if held continuously at temperatures above 32°, hence this latter temperature should usually be chosen as safer than any higher one.

## FRUITS AND NUTS

By DEAN H. ROSE, *senior physiologist*

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits, and nuts are given in table 3. Detailed descriptions of these requirements are given in the text following.

TABLE 3.—Recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of fresh, dried, and frozen fruits, and nuts

Commodity	Temperature	Relative humidity	Approximate length of storage period	Average freezing point <sup>1</sup>
Apples	°F. 31 to 32 and see text.	Percent 85 to 88	See text	°F. 28.44
Bananas	See text	See text	See text	29.36
Blackberries	31 to 32	80 to 85	7 to 10 days	29.15
Cherries	31 to 32	80 to 85	10 to 14 days	27.81
Cranberries	32 to 40	80 to 85	1 to 3 months	27.16
Dewberries	31 to 32	80 to 85	7 to 10 days	
Grapefruit	32	85 to 90	8 to 10 weeks	28.38
Grapes:				
Viniifera	30 to 32	80 to 85	4 to 6 months	24.60
American	30 to 32	80 to 85	3 to 4 weeks	28.16
Lemons	50 to 55	80 to 85	2 weeks to 4 months	28.14
Logan blackberries	31 to 32	80 to 85	2 to 5 days	29.51
Oranges	32	80 to 85	1 to 2 months	(2)
Peaches	31 to 32	80 to 85	1 to 2 weeks	29.41
Pears	30 to 32	85 to 90	See text	(2)
Plums (including prunes)	31 to 32	80 to 85	1 to 2 weeks	28.53
Quinces	31 to 32	80 to 85	3 to 4 months	28.12
Raspberries:				
Red	31 to 32	80 to 85	7 to 10 days	30.41
Black	31 to 32	80 to 85	7 to 10 days	28.76
Strawberries	31 to 32	80 to 85	7 to 10 days	29.93
Dried fruits	32 to 50	70 to 75	1 to 2 years	
Frozen fruits	15 to 18		6 to 12 months	
Nuts	30 to 32	75 to 80	8 to 12 months	(2)

<sup>1</sup> These figures, some of which are based on previously published work by Wright and Taylor (32), are subject to revision whenever further investigation makes this necessary. This column also includes some unpublished data obtained by Wright since 1929.

<sup>2</sup> The figures for oranges are Florida (Valencia), 28.26°; California (Washington Navel), 27.70°. For pears—Bartlett, 28.46°; Winter Nelis, 27.25°; Anjou, 26.93°; and for Persian (English) walnuts, 20°.

## APPLES

(Temperature, 31° to 32° F.; relative humidity, 85 to 88 percent)

There is a wide variation in the storage quality of the different varieties of apples, and of the same variety grown in different regions. For example, McIntosh grown in the Middle Atlantic States is practically an early fall apple not suitable for more than a few days' storage, whereas if grown in northern New York or New England it can be held for as long as 4 months. Such varieties as Northern Spy, Baldwin, and Rhode Island Greening grown in the Cumberland-Shenandoah Valley region or in the hot, irrigated valleys of the Pacific Northwest are very short lived in storage, although suitable for all-winter storage when grown in New England, New York, Michigan, and other northern producing districts.

The keeping quality of apples in storage is also definitely related to the cultural and orchard sanitation practices of the grower, who alone is responsible for the production of sound, properly matured fruit. To have good keeping quality, apples should be fully grown and well colored. When they have reached this stage, they are less likely to scald in storage and are in better condition generally to be held in storage for the maximum period than if they are either immature or overmature.

To insure soundness and good-keeping quality, apples must be not only properly grown and at the proper stage of maturity—they should also be handled in all the operations of picking, grading, packing, and hauling with that degree of care necessary to prevent serious bruising, skin punctures, or other mechanical injuries; and they should be stored as quickly as possible after they are picked. The diseases of apples in storage are discussed in Farmers' Bulletin 1160 (2).

For the storage of most varieties of apples the best results are obtained by maintaining a temperature of 31° to 32° F., and a relative humidity of 85 to 88 percent. Apples from the Pajaro Valley in California, particularly those of the Yellow Newtown variety, should be held at 35° to 38° rather than at 32°, to prevent the development of internal browning or brown core.

If air-cooled storage is used, the temperature obtainable will usually not be much lower than the average of the prevailing outside temperatures. The nearer this is to 32° the better.

The length of time apples can be held successfully in cold storage will vary with the variety, with the region where grown, as well as with their condition when harvested. The following data show about how much time different varieties, as grown in regions to which they are best adapted, require to reach full eating-soft condition when picked at proper maturity and stored immediately at 32° F.

Variety	Months	Variety	Months
McIntosh	2 to 4	Rome Beauty	5 to 6
Grimes Golden	2 to 4	Baldwin	5 to 7
Jonathan	3 to 4	Rhode Island Greening	6 to 7
Tompkins King	4 to 5	Stayman Winesap	6 to 7
Northern Spy	4 to 6	Arkansas	6 to 7
Esopus Spitzenburg	4 to 6	York Imperial	6 to 7
Ben Davis	5 to 6	Yellow Newtown	6 to 8
King David	5 to 6	Winesap	7 to 8
Delicious	5 to 6		

However, "full eating-soft condition" is not what is wanted in apples withdrawn from storage for sale to retailers and by them to the consumer. The dealer would ordinarily require 2 days to a week for disposing of such apples. In determining when to remove apples from storage he must of course consider the market, but he must also allow for the more rapid softening that takes place at the higher temperatures to which they will usually be removed.

Investigations by the United States Department of Agriculture (15) have shown that apples soften approximately twice as fast at 70° as at 50°F., twice as fast at 50° as at 40°, and about twice as fast at 40° as at 32°. It is advisable, therefore to consider the safe storage period, that is, the period which is safe from the commercial point of view, as about 2 weeks to a month shorter than those given in the tabulation above.

Apples in cold storage should be inspected frequently, in order that they may be removed and sold while still in good condition. It is highly desirable that apples intended for storage be wrapped in oiled paper or packed in shredded oiled paper, in order to reduce damage by scald as much as possible (1). Apples should not be stored in the same room with potatoes because of the danger that the former will absorb undesirable odors.

#### APRICOTS

Short storage only. See plums.

#### BANANAS

(Temperature, ripening, 62° to 70° F.; storage, ripe, 56° F.; relative humidity, 80 to 95 percent)

The banana is one of the fruits that must be shipped to market in a green condition, as the ripened product is soft in texture and cannot well be handled without serious injury. The bunches of green bananas as they are received from the Tropics are usually ripened at a temperature of 62° to 64° F., with a relative humidity of 90 to 95 percent. If it is desired to hasten the ripening process a higher temperature can be used (up to 70°) for the first 18 to 24 hours, but the relative humidity should be kept at 90 to 95 percent until the fruit becomes thoroughly colored. After this the temperature should be lowered to 66° and the relative humidity to 80 percent, since with prolonged high humidity the individual fruits will tend to weaken at the stem ends. A much lower humidity will cause undue shrinkage, poor color, and slow ripening. Prolonged exposure to high temperatures will cause poor color and also hasten decay.

The lowest temperature at which green bananas can safely be held in order to delay ripening is about 56°; below this, bananas suffer an injury known as chilling, which prevents their ripening properly when later removed to a suitable temperature, and sometimes results in discolored spots on the skin. The best holding temperature for ripe bananas is generally considered to be 56°, at which they should keep satisfactorily for a week to 10 days.

#### BLACKBERRIES

Short storage only. See raspberries.

## CHERRIES

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Fresh cherries, either sweet or sour, are rarely held in cold storage for more than a few days. If held longer they begin to lose flavor and the bright attractive appearance characteristic of the fresh fruit. The stems may also dry out noticeably, especially if the relative humidity is rather low. Sour cherries are often stored in a frozen state without sugar. They are usually precooled by holding at 32° F. for about 24 hours in the containers in which they arrive from the orchard. They are then put in 50-gallon barrels and frozen at a temperature of about 10° and finally stored at 15° to 20°.

It is probable that the extreme limit for the successful commercial cold storage of fresh cherries at shipping point is about 10 days to 2 weeks. It is doubtful whether fresh cherries from California and the Northwest can be held satisfactorily in cold storage for more than about a week after arrival at eastern markets.

The sweating discussed on page 9 seems to be particularly troublesome on cherries because of the decay frequently associated with it after they are removed from a low temperature (22). Cherries cannot be shipped for any considerable distance without refrigeration, however, and hence are usually exposed for a few days to a week or more to whatever danger there may be from sweating after removal from the car. This means that most commercial lots of cherries should be placed under refrigeration or moved into consumption as quickly as possible after being unloaded.

## CRANBERRIES

(Temperature, 32° to 40° F.; relative humidity, 80 to 85 percent)

Cranberries are stored commercially at temperatures between 32° and 40° F., although better results are obtained from holding them at the lower temperature. Storage for longer than about 3 months is not satisfactory because of the almost universal presence of end rot, a fungous disease which can develop at low temperatures. Shrinkage of the berries as a result of water loss is also a limiting factor.

Cranberries for storage should be culled carefully before storing, so as to minimize as far as possible the danger of loss from decay.

## DEWBERRIES

Short storage only. See raspberries.

## GRAPEFRUIT

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

For best results grapefruit in storage should be held at 32° F. in a relative humidity of 85 to 90 percent. Under such conditions it can usually be held satisfactorily for a maximum of about 10 weeks, provided it is sound but not overmature when stored. If held longer, or at a higher temperature, or a lower humidity, it is likely to show pitting; that is, to become more or less covered with sunken brown spots. It may also suffer from decay, especially if it has been handled

carelessly during the picking and packing process. Overmature or "weak" fruit is likely to pit and decay badly before the end of 2 months, even under the optimum conditions of humidity and temperature mentioned above.

The chief decays of grapefruit in storage are stem-end rot (on Florida and Texas fruit), green-mold rot, and blue-mold rot; the latter is frequently referred to as a contact rot because of its ability to spread from a diseased fruit into a sound one touching it. Stem-end rot is less destructive on grapefruit in storage than are the other two because it is kept in check fairly well by cold-storage temperatures. All three of the rots are more serious at the high humidity it is necessary to maintain in order to keep pitting to a minimum, hence care should be taken that the humidity does not become excessively high at any time. Frequent inspection is desirable throughout the storage period, to determine the condition of the fruit with respect to both pitting and decay.

#### GRAPES

##### VINIFERA

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Large quantities of the European or vinifera grapes, grown principally in California, are stored every year. The most important of the varieties stored are Emperor and Ohanez (Almeria). Olivette de Vendemain, Malaga, Sultanina (Thompson Seedless), Flame Tokay, and Ribier are occasionally stored also. All of these have low freezing points, lower, in fact, than that of any other important fruit, largely because of the high sugar content of grapes. Although for most varieties there is no danger of freezing injury at temperatures as low as 28° F. (3), they are usually held at temperatures of 31° to 32°. A humidity of 80 to 85 percent is desirable to prevent wilting of the stems and fruit.

California grapes for cold storage are packed in kegs or drums in sawdust or in various types of lidded lugs with or without sawdust. Good results are usually obtained, although if the fruit or the sawdust is damp at packing time or becomes so in storage there is danger of damage by mold. Mold may develop also if the grapes have been handled carelessly and there are numerous cracked or loosened berries scattered through the pack. Varieties differ in keeping quality. The best storage varieties, packed in sawdust, can be held 4 to 6 months at 32° F. Emperor and Ohanez seem to hold better than any of the other storage varieties. Treating grapes with sulphur dioxide before placing them in cold storage has been found helpful in preventing decay.

##### AMERICAN

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

The eastern or American varieties of grapes, the most important of which is Concord, are not adapted to long storage and most of them do not hold up well under storage conditions for more than 3 or 4 weeks. After that time they begin to deteriorate in flavor and may suffer heavily from decay if the temperature is not kept

close to 32° F. The Catawba keeps better than most other eastern varieties and if in good condition when stored can be held for 3 to 4 months even in common storage, in the regions where this variety is grown on a commercial scale.

Too low humidity is undesirable for grapes since it causes shriveling, especially of the stems. Stock intended for storage should be handled carefully to avoid cracking of the berries or loosening at the cap stem, because such injuries allow juice to exude and thus furnish favorable conditions for the beginning of decay.

Scuppernong grapes are shipped only short distances if at all and are not known to be held in cold storage anywhere in commercial quantities.

#### LEMONS

(Temperature, 50° to 55° F.; relative humidity, 80 to 85 percent)

From the standpoint of preventing decay (blue-mold rot, green-mold rot, and *Alternaria* rot) in stored lemons, the lowest temperature that can be used without freezing the fruit would seem to be desirable. The difficulty is that at such low temperatures certain nonparasitic troubles develop which are fully as serious as the decay; among these are red blotch, membranous stain, and "peteca", a kind of pitting of the rind. At somewhat higher temperatures (50° to 55° F.) all of these are absent or much less serious and decay is very little greater. The best results are usually obtained by storage at 50° to 55° in a humidity of 80 to 85 percent. Under such conditions lemons can be expected to hold up satisfactorily for periods of 2 weeks to as long as 4 months, depending on their maturity and condition when stored.

If they have been handled carefully they will store better than if they have been injured by rough handling, because there will be fewer clipper cuts, scratches, and bruises and consequently less damage later by green-mold rot and blue-mold rot. The latter is able to penetrate the uninjured skin of lemons but is likely to cause more loss if the skin of the fruit is broken at numerous places. It can also grow from one fruit to another in the package and for this reason is frequently referred to as a contact rot.

Lemons and other citrus fruits should not be stored in the same rooms with dairy products, because of the readiness with which the latter absorb odors. In fact it is better not to keep the two kinds of commodities even in the same building.

#### LOGAN BLACKBERRIES

Short storage only. See raspberries.

#### ORANGES

(Temperature, 32° F.; relative humidity, 80 to 85 percent)

Oranges can be held for 1 or 2 months at 32° F. without serious deterioration in appearance or flavor. However, some decay, chiefly blue-mold rot or green-mold rot, may occur during storage of a month or more, and some fruit may begin to show brown spots on the peel. If stored for longer periods, decay increases and the spotted fruit may gradually turn brown over all or most of the sur-

face. The characteristic flavor also diminishes and a musty flavor develops. The temperature recommended above retards development of decay during the storage period, and for about a week after the fruit is removed from the cold. Among California varieties, Washington Navel oranges are more subject to decay than Valencia oranges. There seems to be little or no difference among Florida varieties in this respect, all of them being affected at times by both blue- and green-mold rot and stem-end rot.

Careful handling is necessary at all times to avoid injuries to the fruit and the decay, chiefly blue-mold rot or green-mold rot, which frequently follows injuries.

A free circulation of air around the boxes is desirable because it aids in keeping down decay and spotting of the fruit. A relative humidity of 80 to 85 percent is sufficient to hold the shriveling of packed oranges to the minimum and retards decay more than does a higher humidity.

Oranges should not be stored with eggs or butter or in places where there is a possibility for the orange odor to penetrate into egg or butter storage rooms.

#### PEACHES

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Peaches are not adapted to cold storage. However, if they are sound and well matured but not overripe, they can be held at 31° to 32° F. for 10 days to 2 weeks with little or no bad effect on the flavor, texture, or appearance of the fruit. Storage for longer periods is usually harmful to all of these characters. The peaches lose their flavor and natural bright color and become either dry and mealy or wet and mushy. In either case they show marked browning of the flesh, especially around the stone.

#### PEARS

(Temperature: Bartlett pears, 30° to 31° F.; fall and winter pears, 31° to 32°. Relative humidity for all varieties, 85 to 90 percent)

##### BARTLETT PEARS

The successful storage of Bartlett pears (14) depends not only on the temperature and humidity in the storage room but also on the condition of the fruit when stored. If the highest quality is to be obtained, Bartlett pears for storage should not be removed from the tree until the ground color begins to lighten and the lenticels have corked over. If picked before reaching that stage, they have a marked tendency to wilt, scald, and break down in storage. They also tend to break down in storage if picked when too ripe. The most desirable temperature for the storage of Bartletts is 30° to 31° F. The relative humidity should range from 85 to 90 percent. The maximum period for the successful storage of Bartlett pears is 30 to 45 days.

##### FALL AND WINTER PEARS

For fall and winter varieties of pears (19) such as Anjou, Bosc, Clairgeau, Comice, Easter, Hardy, Seckel, and Winter Nelis the most desirable storage temperature is 31° to 32° F. The length of time

for which it is safe to store depends on the variety and when it is picked, and also on whether the fruit is shipped directly to a consuming center and there stored, or is stored at shipping point for a time and later shipped to market. Information on these points is given in table 4. In using the table it should be remembered that wide differences in keeping quality are often found in pears from various producing sections of the country.

TABLE 4.—Length of time at various temperatures for safe storage of certain varieties of pears at shipping point and after shipment to market (14, 19)

Storage treatment and variety	Length of storage period	End of storage period
Stored immediately after harvest at 36° F.:		
Hardy	1-2	September to October.
Comice	1-2	October.
Bosc	2-4	November to January.
Clairgeau	3-5	Do.
Winter Nelis	4-5	January to February.
Easter	4-7	February to May.
Stored immediately after harvest at 31° F.:		
Hardy	2-4	October to December.
Comice	2-4	Do.
Bosc	3-5	November to January.
Clairgeau	6	February.
Winter Nelis	6-7	March to May.
Easter	5-7	Do.
Stored after shipping without precooling, but under refrigeration at 31° F.:		
Bosc	2-3	November to December.
Clairgeau	2-6	October to February.
Winter Nelis	2-4	October to January.
Easter	4-6	January to March.
Stored after shipping fruit precooled, and under refrigeration at 31° F.:		
Hardy	2-3	October to November.
Comice	2-3	November to December.
Bosc	2-5	October to January.
Clairgeau	3-6	November to February.
Winter Nelis	6-7	March to May.
Easter	5-7	Do.
Picked in recommended range of 10 to 9 pounds: <sup>1</sup>		
Hardy	(2)	
Picked in recommended range of 11.5 to 9 pounds: <sup>1</sup>		
Comice	(2)	

<sup>1</sup> Degree of firmness as indicated by the pressure tester described by Magness and Taylor (16).

<sup>2</sup> Doubtful if fruit would arrive in firm enough condition to hazard commercial storage.

The commonest and most serious decay of fall and winter pears in storage is gray-mold rot, caused by the fungus *Botrytis*, which is able to spread from decaying to sound healthy fruit. It is frequently called nest rot. Good control can usually be obtained by the use of paper wrappers impregnated with copper (4).

Kieffer pears, if they are sound, firm, and still green in color when stored and are held under the conditions recommended for other fall and winter pears, can be expected to keep satisfactorily for 2 or 3 months. If intended for storage they should be handled with extreme care during the picking and packing process, because even slightly bruised or rubbed places are very likely to turn black and seriously damage the sales value of the fruit. Recent investigations<sup>2</sup> by the Department of Agriculture have proved that a ripening temperature of 65° F. is essential for the attainment of maximum quality in Kieffer pears for either dessert or canning purposes.

\* Unpublished data of the Bureau of Plant Industry.

## PLUMS (INCLUDING PRUNES)

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Plums and prunes (fresh) are not stored extensively and are not adapted to long cold storage. Such varieties as Abundance, Wild Goose, and those of the damson type store better than the softer-fleshed plums such as Santa Rosa, Beauty, Wickson, and Duarte; none of them can be expected to remain in good condition even at 32° F. for more than about 2 weeks. After that time they become too soft for commercial handling and lose somewhat in flavor.

The most important commercial shipping and storage variety is the Italian prune. At a temperature of 32° F., 15 days is about the maximum cold-storage period for this fruit if a shipping period is necessary before the fruit goes on the market. After arrival at market prunes cannot safely be held in cold storage for more than about 3 weeks. If held longer there is danger that internal browning will develop, as well as abnormal odor and flavor.

## QUINCES

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

The behavior of quinces in storage is about the same as that of early winter varieties of apples such as Jonathan and Grimes Golden.

## RASPBERRIES

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Fresh raspberries, blackberries, Logan blackberries, and dewberries are not adapted to storage and are usually not stored commercially. For short periods, 10 days to 2 weeks, they can be kept in fair condition by storage at 31° to 32° F. in a humidity of about 80 to 85 percent.

## STRAWBERRIES

(Temperature, 31° to 32° F.; relative humidity, 80 to 85 percent)

Fresh strawberries are not stored commercially except for very short periods; 10 days is probably the maximum. Even for so short a time as this the temperature must be kept below 40° F. to prevent loss from decay caused by certain low-temperature fungi such as gray mold and *Phytophthora*, the fungus which causes leather rot; 31° to 32° is still better. After about 10 days, sometimes sooner, the fruit loses its fresh bright color, shrivels more or less, and deteriorates in flavor.

## DRIED FRUITS

(Temperature, 32° to 50° F.; relative humidity, 70 to 75 percent)

Dried fruits, including prunes, raisins, apricots, peaches, and figs, are held both in cold storage and in ordinary warehouse storage, at temperatures ranging from 32° to 50° F. A relative humidity of 60 to 65 percent has been found most satisfactory for the storage of these commodities and is in fact about the degree of humidity which large operators often find has become established automatically in large rooms given over wholly to dried fruits. If stored in a ware-

house, the packages of fruit are usually stacked closely together to prevent excessive drying out. Dried fruits do not need the ventilation required by fresh, living fruits and vegetables. The storage room should not be in a basement because of the danger of too high humidity and the consequent development of mold; in fact, an upper floor is preferable, as such a location is usually drier. The storage room should be kept dark and should be well screened to prevent the entrance of insects or rodents.

In cold storage, temperature and humidity conditions are more easily controlled, and vermin are usually held in check or kept out entirely by the low temperature. Dried fruits will usually keep for about a year in cold storage (at 32° F.), whereas in the warehouse or in common storage 4 to 6 months is often the extreme limit. After prolonged storage, even at low temperatures, dried apples darken, and prunes, figs, and raisins tend to "sugar", especially, if their moisture content is high when they are first stored.

#### FROZEN FRUITS

(Temperature, 15° to 20° F.)

Frozen fruits, packed either with or without sugar, should be held in tightly closed containers and preferably at about 15° F. if they are to be stored for several months. The temperature of the fruit should not rise above 20° during the storage period, otherwise there is danger of fermentation and spoilage. The same undesirable changes may occur if the freezing takes place too slowly. Experience has shown, however, that they can usually be prevented if the fruit is sound and clean when packed and the temperature of the freezing room is kept below 10° F. Some packers use a temperature as low as -5° (6).

#### NUTS

(Temperature, 30° to 32° F.; relative humidity, 75 to 80 percent)

The commercial nut crop, including walnuts, filberts, almonds, Brazil nuts, pecans, and peanuts, is usually held in ordinary warehouse storage through the winter following harvest. If any of it is to be kept through the following summer, either as nut meats or in the shell, it should be placed in cold storage in March or early April at a temperature of about 32° F. Some handlers of pecans prefer to put them into cold storage as early as February. The relative humidity for nuts should be maintained at 75 to 80 percent.

The commercial crop of chestnuts is rarely held in any other way than in cold storage, whereas peanuts are held almost entirely in common or warehouse storage. Brazil nuts can usually be kept satisfactorily in warehouse storage, provided they are well dried or cured before being stored. If it becomes necessary or desirable to hold them through the next summer, they should be placed in cold storage.

Nuts that are sound and well cured when stored, and are transferred to cold storage at the proper time, as indicated above, should remain free of mold or rancidity for about a year after harvest.

The fumes of ammonia are very objectionable in rooms where nuts are stored, because they produce a browning or blackening of both shells and meats.

## VEGETABLES

By R. C. WRIGHT, *physiologist*

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of vegetables are given in table 5. Detailed descriptions of these requirements are given in the text following.

TABLE 5.—*Recommended temperature, relative humidity, and approximate length of storage period for the storage of various vegetables*

Commodity	Temper- ature	Relative humidity	Approximate length of storage period	Average freezing point <sup>1</sup>
Asparagus	° F. 32	Percent 85-90	3 to 4 weeks	° F. 29.80
Beans:				
Green or snap	32	85-90	do	29.74
Lima	32	85-90	do	
Beets:				
Topped	32	90-95	1 to 3 months	26.90
Bunch	32	85-90	7 to 10 days	
Broccoli	32	85-90	10 to 15 days	29.20
Cabbage	32	90-95	3 to 4 months	31.18
Carrots:				
Topped	32	90-95	2 to 4 months	29.57
Bunch	32	90-95	7 to 10 days	
Cauliflower	32	85-90	2 to 3 weeks	30.08
Celery	31-32	90-95	2 to 4 months	29.73
Corn (green)	31-32	85-90	See text	28.95
Cucumbers	50-60	80-85	6 to 8 days	30.50
Eggplants	50-60	85-90	10 days	30.41
Endive	32	90-95	2 to 3 weeks	30.90
Garlic (dry)	32	70-75	6 to 8 months	25.40
Horseradish	32	85-90	4 to 6 months	26.40
Jerusalem artichokes	31-32	90-95	2 to 5 months	27.50
Leeks (green)	32	85-90	1 to 3 months	29.20
Lettuce	32	90-95	2 to 3 weeks	31.20
Melons:				
Watermelons	50-55	75-85	do	2 29.20
Muskmelon (cantaloupe)	50-55	75-85	1 to 3 weeks	3 28.80
Honey Dew and Honey Ball	50-55	75-85	3 to 4 weeks	3 29.00
Casaba and Persian	50-55	75-85	4 to 6 weeks	3 28.50
Onions and onion sets	32	70-75	5 to 6 months	30.09
Parsnips	32	90-95	2 to 4 months	28.90
Peas (green)	32	85-90	1 to 3 weeks	30.03
Peppers:				
Chili (dry)	See text	70-75	6 to 9 months	
Sweet	32	85-90	4 to 6 weeks	30.09
Potatoes	36-50	85-90	See text	28.92
Pumpkins	55-60	70-75	2 to 6 months	30.15
Radishes (winter)	32	90-95	2 to 4 months	
Rhubarb	32	90-95	2 to 3 weeks	28.40
Rutabagas	32	90-95	2 to 4 months	27.10
Salsify	32	90-95	do	28.40
Spinach	32	90-95	7 to 10 days	30.64
Squash (winter)	55-60	70-75	2 to 6 months	29.30
Sweetpotatoes	50-55	80-90	4 to 6 months	28.44
Tomatoes:				
Ripe	50-55	80-85	7 to 10 days	30.38
Mature green	55-70	80-85	1 to 6 weeks	30.40
Turnips	32	90-95	2 to 4 months	30.23

<sup>1</sup> See footnote 1, table 3.<sup>2</sup> Flesh.<sup>3</sup> Rind.<sup>4</sup> See text.

## ASPARAGUS

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Fresh asparagus is not usually stored except temporarily when the market is overstocked. Experiments have shown, however, that it can be kept successfully for 3 to 4 weeks at a temperature of 32° F.

Within this temperature range, growth of the stalks, which takes place at higher temperatures, is practically nil. The original tenderness of fresh asparagus, which at ordinary storeroom temperatures is lost soon after cutting owing to the formation of woody tissue, is preserved at this lower range of temperatures. Furthermore, the sugar content, to which asparagus owes some of its flavor and which after cutting rapidly diminishes at higher temperatures, remains practically the same as when the asparagus is cut, if it is put in storage immediately after cutting. Therefore, the sooner asparagus is placed in proper storage after harvesting the better will be its condition when used. The loss of water while in storage or transit is likely to be great if the stalks are not stood on wet moss or other moist absorbent material placed in the bottoms of the crates. In storage, asparagus bunches are sometimes set in water in shallow trays or pans. After a long haul to market asparagus should not be expected to keep in storage for more than 3 to 6 days.

#### BEANS

(Temperature, 32° F., relative humidity, 85 to 90 percent)

##### GREEN OR SNAP

Green beans are usually stored only for short periods. They may be stored at 32° F. and be expected to keep 3 or 4 weeks provided they are placed in storage promptly and in good condition. The humidity should be not lower than 85 percent to prevent wilting, and the hampers or other containers should be so stacked as to allow abundant air circulation. If the containers are packed closely together, the temperature may rise somewhat due to the heat given off by the commodity and more or less rapid decay may be expected. If stored too long the pods will become moldy or slimy.

##### LIMA

Shelled lima beans are sometimes stored in quart baskets and if fresh and sound when stored at 32° F. can be expected to keep in good salable condition for about 15 days. If stored too long the beans tend to fade to a light color and become sticky to the touch if handled. Unshelled lima beans can be held satisfactorily for 3 to 4 weeks.

##### BEETS

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Late beets stored at 32° F. may be expected to keep 1 to 3 months under suitable storage conditions. Either cold storage or cellar storage is suitable, provided the humidity is kept sufficiently high to prevent wilting. Cellar storages often have a higher average temperature range than is recommended, and under these conditions the period of successful storage will be comparatively shorter. The temperature in such storage should not go above 50°. Beets are quite subject to wilting because of the rapid loss of water and should be kept where the humidity is sufficiently high to prevent excessive evaporation.

Before going into storage, beets should be topped and well sorted to remove all diseased specimens and those showing mechanical in-

jury, in order to prevent undue shrinkage because of storage decay. Beets may be stored in ventilated barrels or better in slat crates. Storage in large bulk should be avoided. Bunch beets may be stored for a week to 10 days if the leaves are free of surface moisture and the bunches are not packed so as to exclude air from the tops.

#### BROCCOLI (ITALIAN OR SPROUTING)

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Italian or sprouting broccoli is usually held in storage for only short periods. If in good condition and stored with sufficient ventilation between the packages it should keep satisfactorily for 10 to 15 days.

#### CABBAGE

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

A large percentage of the late crop of cabbage is stored and sold during the winter and early spring, or until the new crop from the Southern States appears on the market. If stored under proper conditions cabbage should keep for 3 to 4 months. The longest keeping varieties belong to the Danish Ballhead class. Cabbage is most successfully held in common storage in the Northern States, where a fairly uniform inside temperature from 32° to 35° F. can be maintained. Many such storage houses are to be found, principally in New York, Pennsylvania, Michigan, and Wisconsin. Cabbage in quantity usually is not held in cold storage because its value does not justify the expense of handling.

Storehouses should be insulated sufficiently to prevent freezing, for although slight freezing does no harm, hard freezing is likely to cause considerable loss. More ventilating capacity than is required for most other vegetables should be provided to carry away the excessive moisture given off by the active respiration of this product and to obtain the maximum advantage of the cold night air during mild weather. Cabbage wilts quickly if held under too-dry storage conditions, hence the humidity should be high enough to keep the leaves fresh and turgid. Bin storage is common, the bins usually being 4 to 5 feet wide and 10 to even 20 feet long and about 5 feet deep. They are best separated by slat partitions with 4-inch air spaces between. Tiers of bins may be built as high as it is convenient to elevate the cabbage when filling. The use of slat shelves with the heads piled 1 or 2 layers deep is considered the best method but is too expensive when large quantities are to be stored.

Cabbage should be handled carefully from the field to the storage. Before it is stored, the roots and all loose leaves should be trimmed away, and the damaged and misshapen heads should be culled out. On removal from storage the heads should be trimmed again to remove loose and damaged leaves.

### CARROTS

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Carrots are stored in fairly large quantities during the winter. The marketing period for stored carrots extends to late winter or early spring when the new crop from the South appears on the market in competitive quantities. They are usually held in common storage in those sections where the storage temperature can ordinarily be held sufficiently low. Carrots are sometimes held in cold storage, although the prices obtained for them do not usually justify this kind of storage.

It is generally considered that very light freezing causes practically no injury to carrots, but they should be protected from severe freezing and are best stored at a temperature of 32° F. They are subject to wilting or drying out if the humidity is not fairly high; for this reason they are more easily kept in a well-ventilated cellar or bank storage. The relative humidity should be maintained at 90 to 95 percent.

Before being placed in storage, carrots should be topped and all misshapen or injured specimens sorted out. The latter are especially objectionable because their presence in a storage lot favors the development of two serious diseases of stored carrots, namely, watery soft rot and bacterial soft rot. Carrots are best kept in slat crates or ventilated barrels, and allowance for air circulation should be made between the containers.

Bunch carrots may be stored for a week to 10 days and the tops still retain a fresh appearance if they are not crowded in storage and the tops are free from surface moisture.

### CAULIFLOWER

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Cauliflower is not usually kept in storage; however, an oversupply in the market can be stored to await more favorable conditions. Experiments have shown that cauliflower can be held satisfactorily for 2 to 3 weeks at 32° F.

### CELERY

(Temperature, 31° to 32° F.; relative humidity, 90 to 95 percent)

Much of the late celery grown in the Northern States, notably New York and Michigan, is put into cold storage to supply the market up to the period in late winter when the competition of new celery from the South renders further holding unprofitable. Considerable celery from Florida is also put into cold storage toward the end of the shipping season from that State and held to supply the market during the summer, or until supplies of early, northern-grown stock appear on the market.

Celery is a rather perishable commodity and under unsuitable storage conditions may suffer severely from the disease known as watery soft rot. This disease originates in the field and is caused by a fungus that is able to develop to some extent even at temperatures of

34° to 36° F. For this reason celery intended for storage should be free from decay so far as can be determined by reasonably careful examination, and if held only in rooms where a uniformly low temperature can be maintained, it should keep from 2 to 4 months. It is best stored at a temperature of 31° or 32°, with a humidity high enough to prevent wilting (90 to 95 percent), and with sufficient air circulation to keep the temperatures at the top and bottom of the room as nearly equal as possible. Considerable heat is given off by celery because of active respiration and the air at the top of a storage room is likely to be 3° to 4° warmer than at the bottom unless special precautions are taken to avoid such a condition. Air circulation can be maintained around the crates by using 1 by 2 or 2 by 2 inch dunage strips between the crates, which should be stacked so as not to touch at the sides.

Celery should not be piled more than four crates high in storage, otherwise there is danger of overheating even with stock that is in prime condition. If it is piled 5 to 8 crates high, as is sometimes done, the room should be watched carefully to see that overheating does not occur.

Some growth takes place in celery while in storage. The central stalks lengthen considerably, obtaining their food at the expense of the outer stalks and the roots. Blanching of the stalks also takes place in most varieties that are put into storage. Some celery is trimmed and washed as it comes from storage, but probably the larger part is shipped out in the original crates in which it was received (27).

#### CORN (GREEN)

(Temperature, 31° to 32° F.; relative humidity, 85 to 90 percent)

Green corn is seldom stored, although there are occasions during the southern shipping season when it might be desirable to put an excess supply of this commodity temporarily into cold storage. Experimental lots of green corn, fresh from the field and chilled in ice water, have been held in cold storage at 32° F. for 30 days without impairment of quality or flavor. The sugar content which so largely determines quality in this product and which rapidly decreases at ordinary temperatures was not reduced. In order to keep this loss of sugar to a minimum and preserve the flavor, corn in the husks as it comes from the field for consumption in the fresh state should be cooled down to 32° to 36° as quickly as possible. This is best accomplished by submerging it in tanks of ice water for at least 30 minutes immediately after removal from the field.

Corn should not be handled in bulk because of its tendency to heat but should be put in baskets or crates which allow air circulation, in order to remove field heat and heat produced by respiration. This commodity as it usually arrives on the market should not be expected to keep in cold storage for more than 4 to 8 days.

#### CUCUMBERS

(Temperature, 50° to 60° F.; relative humidity, 80 to 85 percent)

Cucumbers are usually held in storage only for short periods and cannot be expected to keep satisfactorily for much over 6 to 8 days.

The most favorable storage temperature range seems to be between 50° and 60° F., with a relative humidity of about 85 percent. When held for longer periods of time at 50° or below, dark-colored watery areas appear which are an indication of low temperature injury. These areas soon become infected and mold growth develops. If held at 50° little or no breakdown develops within 4 or 5 weeks, but the cucumbers tend to ripen, the color changing from green to yellow.

#### EGGPLANTS

(Temperature, 50° to 60° F.; relative humidity, 85 to 90 percent)

Eggplants cannot be expected to keep satisfactorily in storage for more than about 10 days.

#### ENDIVE OR ESCAROLE

(Temperature, 32° F.; relative humidity, 90 to 95 percent,

Endive or escarole is a leafy vegetable and therefore is not adapted to long storage. Even at 32° F., which is considered to be the best storage temperature, it cannot be expected to keep satisfactorily for more than 2 or 3 weeks. The storage requirements for endive are practically the same as for lettuce. Like lettuce it should keep somewhat longer than the period just mentioned if it is stored with cracked ice in or around the packages. The relative humidity in rooms where endive is held should be kept at 90 to 95 percent in order to prevent wilting.

A certain amount of desirable bleaching usually occurs in endive that is held in storage.

#### GARLIC (DRY)

(Temperature, 32° F.; relative humidity, 70 to 75 percent)

Garlic is best stored under the temperature and humidity conditions required for onions. If in good condition and well cured when stored, this product should keep for 6 to 8 months. In central California, where considerable garlic is grown, it is frequently put in common storage where it may be held for 3 to 4 months or sometimes longer if the building can be kept cool, dry, and well ventilated. Garlic is stored in loose mesh bags which are piled two layers deep in stacks separated by air spaces. It is essential that garlic be well cured in the field before going into storage.

#### HORSERADISH

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Horseradish should keep satisfactorily for 4 to 6 months if stored under the same conditions as those recommended for carrots.

#### JERUSALEM ARTICHOKE

(Temperature, 31° to 32° F.; relative humidity, 90 to 95 percent)

Jerusalem artichokes, if held in storage at a temperature of from 31° to 32° F. in a relative humidity of 90 to 95 percent, may be expected to remain in good condition 2 to 5 months. At low humid-

ties they shrivel badly and are more likely to decay than if kept in a moist atmosphere. They are sometimes stored in paper-lined, air-tight bags, in which they seem to keep longer, with less wilting and decay.

#### LEEEKS (GREEN)

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

Green leeks are crated and stored under conditions similar to those suitable for celery. If properly handled they should keep satisfactorily for 1 to 3 months in storage.

#### LETTUCE

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Lettuce is sometimes put in cold storage when there is a surplus on the market, or in certain sections when the fall crop is threatened by approaching cold weather. If in good condition when stored it can be expected to keep for 2 or 3 weeks. There is some evidence that it can be kept in better condition if ice is placed in the packages at the time of storage.

One of the most troublesome diseases of lettuce in transit and storage is tipburn of the type that develops in the interior of the head. This injury appears in the field, but in the later stages of the marketing process it is frequently followed by a slimy bacterial decay which may result in serious damage. Frequent inspection of stored lots is desirable.

#### MELONS

(Temperature, 50° to 55° F.; relative humidity, 75 to 85 percent)

Melons of all kinds tend to decay rather rapidly if the humidity is too high. A humidity of about 85 percent should be satisfactory for all varieties. Immature melons will be prevented from ripening satisfactorily if stored at the lower temperature given; therefore this should only be used for ripe or nearly ripe stock.

#### WATERMELONS

The ordinary commercial varieties of watermelons cannot usually be expected to keep in storage for more than 2 to 3 weeks. Experimental lots have been held at temperatures of 32° to 36° F. where decay did not develop as rapidly as at the recommended temperatures. However, there was a tendency for the melons to become pitted or dented and to take on an objectionable flavor after the first week.

#### MUSKMELONS (CANTALOUPES)

The varieties of muskmelons (cantaloupes as known on the market) usually will not keep in storage for more than 1 to 3 weeks. Like watermelons, when stored at 32° to 36° F. for about a week, muskmelons tend to become pitted, and the flavor is impaired.

#### HONEY DEW AND HONEY BALL MELONS

Honey Dew and Honey Ball melons in general tend to keep a little longer in storage than muskmelons. The storage period should be

expected to extend for 3 to 4 weeks. These melons also tend to show some pitting at storage temperatures of 32° to 36° F. and show the pitting more plainly because of their smooth, light-colored surfaces.

#### CASABA AND PERSIAN MELONS

Casaba and Persian melons are relatively good keepers. They will remain in good condition in storage for at least 4 weeks and have been reported to keep as long as 6 weeks.

#### ONIONS AND ONION SETS

(Temperature, 32° F.; relative humidity, 70 to 75 percent)

Onions are held either in common or in cold storage. In the northern onion-growing States, strongly flavored varieties mostly of the globe type are generally held in common or dry storage. The principal northern onion-producing States have a sufficiently low average winter temperature so that onions can be successfully held in common storage there during the winter months. About one third of the onion crop of these States, however, is put into cold storage for consumption late in the spring. About the first of March is considered as late as onions should be held in common storage, because after this time there is danger of sprouting. The mild or Bermuda types, such as those produced in Washington, southern California, Texas, and other States where the climate is not suitable for common storage, are usually consumed shortly after being harvested. These onions can be, and limited quantities are, held in cold storage, but usually for much shorter periods than the globe varieties because of their poorer keeping qualities. The Spanish or Valencia type of onions grown in this country are often stored and, if well matured, are considered capable of storage for practically as long as the globe type.

A comparatively low relative humidity (70 to 75 percent) is very desirable for the successful storage of onions. At higher humidities, in which many other vegetables keep best in storage, onions are disposed to root growth and decay. The commonest form of the latter is gray-mold rot occurring at the top of the bulb, whence its name "neck rot" (29). The fungus causing it can develop to some extent even at 32° F., hence onions intended for storage should be carefully sorted over to remove all diseased bulbs. A uniform temperature of 32° is found to be sufficiently low to keep onions dormant and reasonably free from decay provided they are in good sound condition and well cured when stored.

Onions are not perceptibly injured by slight freezing if allowed to thaw out slowly and without rough handling. In cold storage they are usually held in bags of 100 pounds each, which are best piled in pairs laid crosswise in stacks 5 or 6 sacks high. The stacks should be set a few inches off the floor on 2 by 4 inch strips, and the individual stacks separated by a few inches of space to allow for air circulation. When kept in common storage, onions are best stored in slat field crates holding about 1 bushel, rather than in bags. Before being placed in storage onions should be well dried or cured in the field for a period of 4 to 6 weeks and all decayed specimens or those showing thick or "bottle" necks should be sorted out.

Onion sets are usually held in common storage. They require nearly the same conditions as large onions and are best stored in shallow slat-bottom crates or trays not over 4 inches deep and about 5 by 5 feet in some districts or 2 by 3 feet in others. The corner posts of the crates should project about an inch above the side pieces in order to prevent the crates from resting tightly on each other when stacked and to allow air circulation between them. Because of their size, onion sets tend to pack closely in the crates, hence it is essential to allow as much air circulation as possible and to maintain a comparatively low humidity.

#### PARSNIPS

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Parsnips have nearly the same storage requirements as carrots, and should keep for 2 to 4 months. They are not injured by slight freezing while in storage but should be protected from hard freezing and should be very carefully handled while in a frozen condition. Parsnips dry out readily in storage, hence it is essential that the humidity of the storage place be kept relatively high. Parsnips are sometimes stored in sand or clean soil to prevent wilting, but they will keep in good condition when held in barrels or crates if the proper humidity is maintained.

#### PEAS (GREEN)

(Temperature, 32° F.; relative humidity, 85 to 90 percent)

The same storage conditions are required for green peas as for beans. Shortly after picking, green peas tend to lose part of their sugar content on which much of their flavor depends. They cannot be expected to keep in salable condition for more than 1 to 3 weeks unless packed in crushed ice, in which condition the storage period may be extended perhaps a week.

#### PEPPERS

#### CHILI (DRY)

(Temperature, see text; relative humidity, 70 to 75 percent)

Chili peppers are usually picked when ripe and then dried and allowed to equalize in moisture content in covered piles. Water is usually added to the peppers after drying, and as a result they become less brittle. They are then packed tightly by tamping into sacks holding 200 to 300 pounds and stored in warehouses for a period often lasting for 6 to 9 months.

The temperature of the warehouses depends to some extent on their construction and the way in which they are managed but chiefly on the outside temperature. In southern California, where a large part of the commercial crop of Chili peppers is produced, the outside temperature ranges from 50° to 80° F. during the usual storage period.

The moisture content of Chili peppers when stored is generally low enough (10 to 15 percent) to prevent mold growth; the chief storage trouble is insect infestation. Some manufacturers of Chili-pepper products hold part of their supply of the raw material in cold

storage if this seems necessary, but they prefer to grind the peppers as soon as possible and store them in the manufactured form in airtight containers.

#### SWEET

(Temperature, 32° F.; humidity, 85 to 90 percent)

Sweet or bullnose peppers, if in good condition, may readily be kept fresh in storage for a month to 6 weeks at a temperature of 32° F. A humidity of 85 to 90 percent is desirable to prevent shrinkage (11).

#### POTATOES

(Temperature, 36° to 50° F.; humidity, 85 to 90 percent)

Potatoes are stored either in cold or common storage, but the greater part of the crop that is stored is held in common storage (26). Like most other vegetables that can be held for relatively long periods in common storage, only in the northern tier of States where a sufficiently cold winter climate prevails can potatoes be successfully kept during the fall and winter months. In either cold or common storage a temperature of 40° F. is as low as table or seed stock need be kept during the first few months after harvest. At temperatures below this, there is a tendency for potatoes to become undesirably sweet. However, if they should become too sweet, a few days' exposure to ordinary living-room temperature will partly restore the natural flavor. At 40° potatoes will remain dormant 3 to 5 months after harvest, depending on the variety. If it is desired to keep them longer than this, as is often the case with seed stock, the temperature may be lowered to 36° or 38° F., where they should remain dormant indefinitely.

Recent investigations (18) have indicated that potatoes stored at 50° to 60° F. have better texture, color, and flavor when cooked or made into chips than the same stock stored at lower temperatures, although the higher temperatures are not suitable for long-time storage. When storing potatoes at these higher temperatures, sprouting will more quickly become apparent. A limited amount of sprouting does not injure potatoes for food purposes, but it makes the stock difficult to market because usually only dormant potatoes are wanted. After sprouting has started it can be checked by lowering the storage temperature.

The relative humidity of a potato-storage house should be 85 to 90 percent to prevent undue shrinkage through loss of water. In cold storage potatoes are generally kept in sacks holding from 100 to 150 pounds net; in common storage they are usually placed in bins holding from 150 to as much as 1,000 bushels or more. Farther north, as in Maine or northern New York where the average temperature is sufficiently low, the large bin storage is used with success, but in the States in the latitude of Pennsylvania it is doubtful if potatoes should be stored in such large units. Potatoes are readily injured by even slight freezing, which takes place at about 29° F. or slightly below, hence common-storage buildings should be sufficiently insulated to prevent freezing. Insulation will also prevent the condensation of moisture on the walls and ceilings, and the consequent undesirable

wetting of stored stock, which favors the development of decay (24). Sufficient means of ventilation should be provided in common storage to take advantage of the cool night air in mild weather which will aid in preventing excess moisture and maintain a lower average temperature.

Potatoes intended for storage should be handled carefully to avoid bruises and cuts, otherwise they are likely to be damaged by various forms of decay before the end of the storage period.

#### PUMPKINS

(Temperature, 55° to 60° F.; relative humidity, 70 to 75 percent)

In general most varieties of pumpkins will not keep in storage as long as the usual storage varieties of squash. Such varieties as Connecticut Field and Cushaw are relatively poor keepers and cannot be expected to hold in good condition more than 2 or 3 months. Varieties like Large Cheese and Table Queen will keep 3 to 6 months.

Hard-shell squashes, such as the Hubbards, can be successfully stored for 6 months or longer.

All stock should be well matured, carefully handled, and free from injury or decay when put in storage. The best storage temperature appears to be from 55° to 60° F. with a relatively low humidity of about 70 to 75 percent. Investigations have shown that a preliminary curing at from 80° to 85° F. for about 2 weeks is of benefit in ripening immature specimens and in healing mechanical injuries incident to harvesting.

#### RADISHES (WINTER)

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Winter radishes require the same storage conditions as carrots and should keep in good condition for 2 to 4 months.

#### RHUBARB

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Rhubarb stalks if fresh and in good condition may be stored for 2 to 3 weeks. The bunches should be packed in crates which are stacked to allow ample air circulation on all sides, otherwise there is danger of heating and also mold growth.

#### RUTABAGAS

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Rutabagas require the same storage conditions as carrots and should keep satisfactorily under such conditions for 2 to 4 months.

#### SALSIFY

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Salsify has the same storage requirements as carrots. The roots are not injured by slight freezing but should be carefully handled while frozen. Under the conditions specified, they should keep for 2 to 4 months.

**SPINACH**

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Spinach is usually stored only for short periods. It should keep fairly well for a week or two after cutting. If crushed ice is used in the packages, this period can be extended somewhat.

**SQUASHES**

See pumpkins.

**SWEETPOTATOES**

(Temperature, 50° to 55° F.; relative humidity, 80 to 85 percent)

The requirements for the successful storage of sweetpotatoes differ from those recommended for most other vegetable crops. When freshly dug sweetpotatoes are to be stored for any length of time they should be given a preliminary curing treatment to permit the healing of all wounds or abrasions incident to harvesting and handling, in order to prevent the entrance of decay organisms.

The curing and storing are done in the same house so that the potatoes do not have to be moved after the curing treatment. When commercial lots are handled the storage house is generally of special construction with sufficient insulation to maintain a uniform temperature, and some means of ventilation that will insure the desired humidity. Provision should be made for heating the building during the curing process and for holding the proper storage temperature afterward. The curing process ordinarily takes from 10 to 14 days, during which the house is kept at a temperature of 80° to 85° F., with a relative humidity of 80 to 90 percent. After the curing period the storage temperature is allowed to drop to a range of 50° to 55° with a humidity of 80 to 85 percent. Short periods of a few hours at temperatures somewhat lower than 50° need not cause alarm, but prolonged periods should be avoided because of the danger from certain types of decay which are more likely to develop at temperatures below the range given (10, 28).

Only well-matured stock that is practically free from mechanical injury or decay should be used for storage. Sweetpotatoes are usually stored in slat crates of about a bushel capacity or in bushel baskets. Shallow bins are sometimes used.

**TOMATOES**

(Temperature, ripe, 50° to 55° F.; mature green, 55° to 70° F.; relative humidity, 80 to 85 percent)

Ripe tomatoes are held in storage only temporarily and should not be stored at temperatures lower than 50° F. At 50° to 55°, if not already soft ripe, they will keep in good condition for a week to 10 days; at temperatures lower than this they sometimes show a tendency to break down.

Green tomatoes are best kept at a temperature not lower than 55°. At this temperature, ripening progresses slowly but satisfactorily and mature green tomatoes can be kept for 1 to 6 weeks before becoming overripe. At temperatures below 55° green tomatoes do not ripen well, and if kept there more than 5 to 8 days and then

moved to warmer conditions they usually do not ripen satisfactorily. Exposures up to 5 to 8 days to a temperature of 40° or even somewhat less do not usually prevent mature green tomatoes from ripening satisfactorily when later removed to a favorable temperature. If fairly rapid ripening is desired, temperatures from 60° to 70° should be used. At 70° or above, ripening is accelerated, but so also is the development of decay which will be found difficult to control. The relative humidity of tomato storage or ripening rooms should be from 80 to 85 percent (31).

#### TURNIPS

(Temperature, 32° F.; relative humidity, 90 to 95 percent)

Turnips require the same storage conditions as carrots. They can be expected to keep for 2 to 4 months.

#### CUT FLOWERS, FLORISTS' GREENS, RHIZOMES, TUBERS, CORMS, AND BULBS

By T. M. WHITEMAN, *junior horticulturist*

The recommended temperature, relative humidity, and approximate length of storage period for the commercial storage of cut flowers, florists' greens, rhizomes, tubers, corms, and bulbs are given in table 6. Detailed descriptions of these requirements are given in the text following.

TABLE 6.—Recommended temperature and approximate length of storage period for cut flowers, florists' greens, rhizomes, tubers, corms, and bulbs<sup>1</sup>

Commodity	Tem- pera- ture (° F.)	Approximate length of storage period	Commodity	Tem- pera- ture (° F.)	Approximate length of storage period
Cut flowers: <sup>2</sup>			Cut flowers—Contd.		
Babysbreath	40	3 to 4 days.	Hyacinth	35-40	1 week.
Bouvardia	40	7 to 10 days.	Iris	40	7 to 10 days.
Butterflybush	40	3 to 4 days.	Laceflower	40	3 to 6 days.
Calendula	40	3 to 6 days.	Lily:		
Calla	40	10 days.	Easter	35	1 month.
Candytuft	40	3 to 6 days.	Goldband	35	Do.
Carnation	40	1 week.	Speciosum	35	Do.
China-aster	40	7 to 10 days.	Lily - o f - the - valley.	40	1 week.
Chrysanthemum	35	2 weeks.	Lupine	40	3 to 6 days.
Clarkia	40	3 to 6 days.	Narcissus	32-36	2 weeks.
Columbine	40	3 to 4 days.	Orchid, Cattleya	45-50	1 week.
Coreflower	40	3 to 6 days.	Peony:		
Crocus	32-36	2 weeks.	Tight buds	35	3 to 4 weeks.
Dahlia	40	7 to 10 days.	Loose buds	35	10 to 14 days.
Daisy, English	40	3 to 6 days.	Phlox	40	3 to 4 days.
Delphinium:			Poinsettia	50	Do.
Hardy lark- spur.	40	Do.	Primrose	35-40	Do.
Annual lark- spur.	40	3 to 4 days.	Rose	40	1 week.
Feverfew	40	3 to 6 days.	Snapdragon	40	3 to 6 days.
Forget - me - not, true.	40	3 to 4 days.	Snowdrop	32-36	2 weeks.
Foxglove	40	Do.	Squill	32-36	Do.
Freesia	32-36	2 weeks.	Statice	35-40	3 to 6 weeks.
Gaillardia	40	3 to 6 days.	Stevia	40	3 to 4 days.
Gardenia	45-50	1 week.	Stock, common	40	3 to 6 days.
Gladiolus	35	2 weeks.	Strawflower	35-40	1 month.
Heath	40	7 to 10 days.	Sweet pea	40	3 to 4 days.
			Tulip	32-36	2 weeks.
			Violet	40	3 to 6 days.

<sup>1</sup> See footnote 1, table 3. The average freezing points which have been determined on certain cut flowers, bulbs, etc., are as follows: Gardenia, 28.30° F.; Easter lily, 27.50°; orchid (*Cattleya*), 30.08°; peony, 29.05°; rose, 30.04°; Oregon wild fern, 23.60°; holly, 26.50°; gladiolus (bulbs), 26.66°; hyacinth (bulbs), 28.70°; Regal lily (bulbs), 27.10°; tulips (bulbs), 25.39°; tulip (bloom), 28°; narcissus (daffodil, bulb), 30.1°; narcissus (Paper White, bulb), 28.9°.

<sup>2</sup> Approximately 80 percent relative humidity.

TABLE 6.—Recommended temperature and approximate length of storage period for cut flowers, florists' greens, rhizomes, tubers, corms, and bulbs—Contd.

Commodity	Tem- pera- ture (° F.)	Approximate length of storage period	Commodity	Tem- pera- ture (° F.)	Approximate length of storage period
Florists' greens: <sup>2</sup>			Rhizomes, tubers, etc.—Continued		
Ferns:			Crocus.....	55-60	4 to 6 months.
C o m m o n wood.	32-45	2 weeks to 4 months.	Dahlia.....	45-50	6 to 7 months.
Dagger.....	40-45	Do.	Freesia.....	55-60	4 to 6 months.
Asparagus.....	40-45	7 to 10 days.	Gladiolus.....	35	7 to 8 months.
Galax.....	32-45	2 weeks to 4 months.	Hyacinth.....	55-60	4 to 6 months.
Holly.....	32	1 month.	Lily - of - the - val- ley.	25-28	12 to 14 months.
Laurel, mountain- ing.	32-40	3 to 6 weeks.	Lily:		
Leucothoe, droop- ing.	32-40	Do.	Easter.....	35	6 to 8 months.
Lycopodium.....	32-45	2 weeks to 4 months	Regal.....	35	Do.
Rhizomes, tubers, corms, and bulbs: <sup>3</sup>			Narcissus.....	55-60	4 to 6 months.
Begonia, tuber.....	45	4 to 6 months.	Snowdrop.....	55-60	Do.
Caladium.....	45	Do.	Squill.....	55-60	Do.
Calla.....	35	6 to 8 months.	Taro.....	45	Do.
Canna.....	45-50	6 to 7 months.	Tuberose.....	40-45	6 to 8 months.
			Tulip.....	50-55	4 to 6 months.

<sup>2</sup> Approximately 80 percent relative humidity.<sup>3</sup> Approximately 75 percent relative humidity.

## CUT FLOWERS

Cold-storage rooms for cut flowers are operated mainly by wholesale florists in the large cities. Here flowers are usually held for short periods only. The temperatures given herein are recommended to insure a reasonably long life for flowers after their removal from storage.

Cut flowers in storage should be kept with the stems well submerged in water. They should not be crowded in the containers because of the danger of mechanical injury and the decay that may result because of lack of ventilation. In most cases care should be taken not to spill water on the blooms since these usually discolor quite readily.

Chrysanthemums (*Chrysanthemum hortorum*) and gladioli (*Gladiolus* spp.) may be stored at 35° F. for 2 weeks, and usually remain very salable. Longer storage is possible, though frequently not practicable. These flowers are usually tied in bunches of 12 and 25, respectively, but are not wrapped when placed in storage. Pompons, however, are sold in bunches of various sizes.

As a rule the proper cutting stage for the large-flowering types of chrysanthemums is just after the green color in the center of the flower has disappeared. No general rule can be given for pompons, since several varieties, especially some of those in the anemone group, need more development on the plant than the single varieties.

Gladioli should be cut when 3 or 4 of the lower buds show color and are partly opened. For distant shipments before storage the flowers should show color but should be in the tight bud stage.

Easter lily (*Lilium longiflorum*), common peony (*Paeonia officinalis*), Chinese peony (*P. albiflora*), Speciosum lily (*L. speciosum*), Regal lily (*L. regale*), and goldband lily (*L. auratum*) can be held at 35° F. for comparatively long periods, although 30 days is usually the maximum storage period. The lilies in this group should be cut

for storage when the corolla is about one half opened, or just before the tips begin to reflex. Lilies forced at relatively high temperatures should be kept at a temperature of about 50° for a preliminary period of about 24 hours before being put at 35°. Peonies showing color in the tight bud may be stored at 35° for a month or more, but they seldom give satisfaction for decorative purposes without special handling; in the loose-bud stage they may be held satisfactorily for 10 days.

The cut blooms of callas (*Zantedeschia aethiopica* and *Z. elliotiana*) may be stored when fresh for as long as 10 days at 40° F., and will be in good condition upon removal. Calla blooms should be gathered just before the spathe shows signs of curling downward. Callas that have been subjected to hard forcing should be held for about 24 hours at a temperature of 50° previous to storage at 40°. When the blooms are gathered they should be pulled, not cut, otherwise the stems will split at the cut ends and curl after a few days in storage. The pulling method separates the stem from the rhizome leaving no useless appendage. Although the blooms are sometimes removed from the plant by cutting, the stub left on the plant will probably rot and thus may serve as a place of entrance for disease organisms. Pulling, however, is much easier with potted callas than with those planted in beds or benches. Callas intended for storage should be tied at the bottom and also loosely tied below the blooms. They are usually put up in lots of 1 dozen. The container should be about 2 feet high so that the stems will stand deep in water.

Lupine (*Lupinus*), clarkia (*Clarkia* sp.), common stocks (*Matthiola incana*), candytuft (*Iberis*), delphinium, hardy or perennial larkspur (*D. formosum* and hybrids), cornflower (*Centaurea cyanus*), feverfew (*Chrysanthemum parthenium*), common snapdragon (*Antirrhinum majus*), blue laceflower (*Trachymene caerulea*), English daisy (*Bellis perennis*), calendula or pot-marigold (*Calendula officinalis*), common perennial gaillardia (*Gaillardia aristata*), and sweet violets (*Viola odorata*) should not be held at temperatures lower than 40° F., and cannot be stored with good results for more than a 3- to 6-day period. Violets are usually made up in bunches of 100, supported underneath by a few galax leaves and wrapped with a light waxed paper.

Columbine (*Aquilegia* sp.), stevia (*Piqueria trinervia*), babys-breath (*Gypsophila paniculata*), delphinium, annual larkspur, baby primrose (*Primula forbesi*), sweet pea (*Lathyrus odoratus*), true forget-me-not (*Myosotis scorpioides*), and orange-eye butterflybush (*Buddleia davidi*), all have flowers whose petals shed quickly, almost regardless of temperature. They cannot be held much lower than 40° F., nor for longer than 3 to 4 days without impairing the keeping quality after removal. Forced *Buddleia* is sold by the dozen. The others mentioned are bunched in lots of 25. None of these is wrapped for storage.

Orchids and gardenias (*Gardenia florida*, *G. veitchii*, and *G. fortunei*) are not customarily stored for long periods. However, they may be kept in storage in good condition for about a week at a temperature of 45° to 50° F. They keep best when cut just after they have reached a salable condition.

Carnations (*Dianthus caryophyllus*) are preferably held at a temperature of 40° F., although 35° may be used for comparatively long periods. The best cutting stage is immediately after the center of the flower has developed sufficiently to be considered salable. They are customarily put up in lots of 25 by the grower, and should be tied securely at the bottom and more loosely below the blooms.

Roses for nearby markets should be cut in the loose-bud stage; if they are to be shipped to distant markets they should be in the tight-bud stage but showing color. In the loose-bud stage they may be held at 35° to 40° F. for 1 week; stored at lower temperatures the subsequent keeping qualities are often impaired. They are usually tied by the grower in bunches of 25 and the buds and upper parts of the stems are wrapped tightly in waxed parchment paper to prevent bruising and possible opening of the petals.

Dahlias (*Dahlia* sp.), China-asters (*Callistephus chinensis*), sweet bouvardia (*Bouvardia humboldti*), heath (*Erica* sp.), and the various forced irises may be held for 7 to 10 days at 40° F. They usually are handled in lots of 1 dozen, tied, but not wrapped.

Statice, including bigleaf and notchleaf, sea-lavender (*Limonium latifolium* and *L. sinuatum*, respectively), and strawflower (*Helichrysum bracteatum*) may be kept at 35° to 40° F. for 3 to 6 weeks. They may be dried, with the retention of their original color and shape; strawflowers are usually dried instead of being stored to retain their freshness.

Common foxglove and common white foxglove (*Digitalis purpurea* and *D. purpurea alba*, respectively) and garden phlox (*Phlox paniculata*) are not usually satisfactory for storage, but may be held for 3 or 4 days at 40° F.

Cut poinsettias (*Poinsettia pulcherrima*) sold during the Christmas season usually need not be stored for the few days between their arrival at the wholesale house and the day of sale. If holding is necessary, storage at about 50° F. is recommended. Any change of environment, such as improper storage, will increase the apparently inherent tendency of poinsettias to shed their foliage. They should be cut when showing sufficient color to be salable. Searing the cut ends with boiling water is a practice usually followed to prevent undue loss of sap previous to or during storage.

Cut lilies-of-the-valley (*Convallaria majalis*) are kept satisfactorily at 40° F. and may be held for 1 week at this temperature; if kept longer the lower bells often become watery in appearance (30). The proper cutting stage is just after the terminal bell has lost its deep-green color. It should be of a yellow-green appearance, the lower 3 or 4 bells at this time being well opened. They are usually tied with foliage in bunches of 25, and are better wrapped loosely in heavy waxed paper, leaving the tops and bottoms of the bunches open.

Hyacinths, tulips, narcissus, freesias, squills, snowdrops, and crocuses can usually be held satisfactorily for 2 weeks at 32° to 36° F.

Spikes, such as snapdragon, should be cut just after the lower 5 or 6 flowers have fully opened; umbels, such as blue laceflower, should be cut just after they develop to a salable condition; flowers formed in heads usually should be cut after the outermost petals are fully developed and just before stamens appear in the center of typically

single heads or after the center has become closed with petals in double sorts; corymbs, such as candytuft, are usually best when cut after three fourths of the lower flowers are opened; those described as thyrses or corymbose cymes, such as the lilac, should be cut when about two thirds of the determinate branches are developed; cymose clusters, such as babysbreath, should be cut after a few of the terminal flowers have developed.

#### FLORISTS' GREENS

Fern asparagus (*Asparagus plumosus*) and smilax asparagus (*A. asparagooides*) are usually shipped in crates. The turnover of these greens is rapid and shipments are arranged so that storage for longer than 3 or 4 days is usually unnecessary, but they may be kept in the case for 7 to 10 days at 40° to 45° F. The sprays of *A. plumosus* are tied in bunches of various sizes. Smilax is packed in the crates in various lengths or "strings." The commercial popularity of *A. sprengeri* has declined to a point where it is produced and used chiefly by small retail growers.

Drooping leucothoe (*Leucothoe catesbaei*) and mountain-laurel (*Kalmia latifolia*) sprays may be held at 32° to 40° F. for 3 to 6 weeks in good condition. They are usually tied in bunches and kept standing in containers of water.

Galax (*Galax aphylla*), groundpine (*Lycopodium* sp.), dagger ferns, common woodferns and various species including *Dryopteris intermedia*, packed in crates, may be held at 32° to 45° F., depending on the length of time it is desired to keep them. At 32° they may be expected to keep 3 to 4 months, whereas at 45° they may be kept for but 2 to 3 weeks in good condition. They are not put in water, but, if stored loose they are kept moist by occasional sprinklings. If held in wooden cases or packed in such a way as to prevent excessive drying out by direct air currents, no sprinkling is necessary. Galax is usually tied in bunches of 25; the ferns are tied in lots of 50, but both are customarily sold by the hundred. Those who make a business of gathering the greens in this group sometimes store them in coldframes, covering them with about 6 inches of some material such as sphagnum moss or leaves, and shading or using sash as the weather demands. Handled in this way, shipments can be made at any time. Others who might be termed "brokers" have many employees gathering galax and ferns, and store their entire holdings in cold-storage warehouses; this is the method commonly employed for storage and it usually gives satisfaction.

Holly sprays or wreaths can usually be held satisfactorily for approximately 1 month at a temperature of 32° F. and a relative humidity of about 80 percent.

#### RHIZOMES, TUBERS, AND CORMS

Lily-of-the-valley pips or crowns may be held in cold-storage warehouses at a temperature range of 25° to 28° F. (30) for 15 to 17 months, although after about 12 months increasing deterioration in quality becomes noticeable. The pips are tied in bundles of 25 with string or willow ties and are packed in wooden cases of various sizes containing from 250 to 2,500 pips.

Taro (*Colocasia esculenta*), spotted caladium (*C. neoguineensis*), and tuber begonias (*Begonia tuberhybrida*) may be held at 45° F. and a humidity of 75 to 80 percent for several months. They should be packed in dry sawdust or peat.

Cannas (*Canna indica*), dahlias (*Dahlia* sp.), and peonies (*Paeonia* sp.) may be stored at 45° to 50° F. over a period of 6 to 7 months with a humidity of 70 to 80 percent. They are usually packed in dry soil or sawdust.

*Gladiolus* sp. (mostly hybrids) stored at 35° F. and at a humidity of 70 to 75 percent will keep in good condition for the normal storage period of 7 to 8 months. They should be stored dry in shallow trays with ample ventilation, but only after a curing period of 3 to 6 weeks in an open or well-ventilated shed.

Common and golden callas (*Zantedeschia aethiopica* and *Z. elliotiana*) stored at 35° F. and at a humidity of 70 to 75 percent in dry soil or peat will keep for many months, if it is necessary to store them. The normal rest period in the forcing cycle is during May, June, and July. Unless water is withheld during this period complete dormancy will not exist. Therefore, storage in a dry condition is essential, with sufficient humidity to prevent undue shriveling.

#### BULBS

Most varieties of *Narcissus* sp., hyacinths (*Hyacinthus orientalis*), freesias (*Freesia refracta alba*), tulips (*Tulipa* sp.), squills (*Scilla* sp.), snowdrops (*Galanthus nivalis*), *Crocus* sp., and similar bulbs may be held in common storage for several months. However, many of them are still imported in large numbers and these are usually not stored, since better results are obtained by planting them as soon as they arrive.

The genus *Lilium*, of which there are approximately 50 species, like most other bulbs, give best results if planted when received. However, as Easter lilies are forced during the entire year, it becomes necessary to provide cold-storage conditions suitable for satisfactory holding until they are wanted for planting. The bulbs should be packed in boxes in thoroughly dry soil, if rooting and desiccation are to be prevented. A temperature of 32° F. with a humidity of 75 to 80 percent is recommended.

Tulips are usually not stored in any packing material, although this may be advantageous for long storage. Temperatures of 36° to 38° F., except for short storage, are considered rather low for tulips shipped in from the West in which the buds are already formed. The best storage temperature for shipped tulips is between 50° and 55°.

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